EXHIBIT 3

ATF Fire Research Laboratory Technical Bulletin

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Arc Mapping as a Tool for Fire Investigations

Abstract

The purpose of this Technical Bulletin is to address statements that are contained in *Arc Mapping: New Science or New Myth?,* which was presented at the Fire and Materials Conference in February 2017. The paper's interpretations and analysis of the published literature, the limitations it places on the process of arc mapping, and the conclusion that arc mapping is applicable to less than 1% of fire scene investigations are misleading. This bulletin addresses some of these issues.

Statement of Issue

Arc Mapping: New Science or New Myth? [1] was presented at the 2017 Fire and Materials Conference in San Francisco, CA. While the paper does address some valid concerns, such as the necessity that the investigator should have knowledge of electricity and electrical systems, it also presents a misleading view on the process of arc mapping and suggests unnecessary limitations on its use in fire investigation.

According to the author:

> *"The technique* [arc mapping] *is valid and applicable only in some very limited scenarios."*
>
> *"Careful consideration of engineering principles and large-scale experimental studies on the subjects indicates that the relevance and prominence of arc mapping as a leading indicator of fire origin is greatly overstated."*
>
> *"…in the majority of cases, principles of science do not allow conclusions to be drawn from an arc map with regards to the origin of the fire. In the cases where valid conclusions can be drawn, they only establish the local direction of fire movement at a specific locale, and do not suffice to identify the area of origin of the fire. Reliable conclusions on the local direction of fire movement can be drawn in those cases where the branch circuit has a sever-arc or a weld-arc, and an additional arc downstream of this location. But the experimental data indicate that the probability of a building's branch circuit exhibiting these conditions for allowing a valid arc-mapping conclusion is less than 1%, and is calculated to be 0.7%. This pertains to solid-core conductors; not enough research has been conducted on stranded wire arcing to be able to draw statistical conclusions."*
>
> *"The totality of published experimental results does not support the ability of arc patterns to identify the area of fire origin."*
>
> *"…it is important that NFPA 921 reduce the implied general utility of the method and provide more explicit discussion of its limitations and of those circumstances where arc mapping is a valid method for assisting in the determination of a fire origin."*

Engineers at the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) Fire Research Laboratory (FRL) reviewed the manuscript in the fall of 2016 prior to submission for Fire and Materials. The FRL recommended that the paper should not be published without significant modifications.

Analysis of Issue

In the abstract of the paper, the author stated that the following arc mapping "myths" are commonly applied in fire investigation today:

1) *"An abundance of arc beads at a given locale means that fire originated in that area, while a paucity of arc beads indicates that it did not."*
2) *"When multiple arcs are present on a circuit, the direction of arcing will necessarily proceed upstream towards the power source."*
3) *"If an appliance is the victim of a fire, internal arcing will be primarily near the exterior of the unit, while arcing deep inside indicates a fire origin at that place."*

None of these "myths" are used in curriculums taught by the ATF, the International Association of Arson Investigators (IAAI), or at the U.S. Fire Administration's National Fire Academy. Furthermore, these "myths" are not published in **NFPA 921: Guide for Fire and Explosion Investigations** [2], the most commonly used guide in the industry. While these "myths" likely originated as hypotheses, they have since been disproven or modified into the methodology used today.

Furthermore, the author's statement that arcing inside an appliance is indicative of failure ignores much of the information presented by Kovarsky [3] and assumes that no further analysis of the appliance is conducted. The only definitive conclusion that can be drawn from the presence of arc melting is that the conductor(s) or components were energized at the time of the fire. The investigator should consider the circuitry of the appliance, fuel and ventilation conditions, and protective barriers before drawing any conclusions about the arc melting. Arc melting found within an appliance should warrant further inspection of that appliance.

The author cited a 2005 paper by West and Reiter that presented the results of three full-scale test burns in a motel [4]. The author stated that the results of this study were inconclusive, pointing to the lack of arc sites clustered around a small area, and that therefore arc mapping did not narrow down the area of origin. However, the configuration of the circuits within the room was not accounted for. The arc mapping diagrams from the paper are shown in Figures 1A, 2A, and 3A. A red circle has been placed in these figures to denote the origin of the fires. Without considering the circuit configuration, arc mapping would appear to add little, if any, value to the determination of the origin.

A method for analysis suggested by the FRL was to color-code the circuits and arcing locations based on the direction of the circuit runs. The power source for each circuit was denoted by the rectangle at the end of each line. The "load" side of each circuit was left open. The color coding of the circuits can be seen in Figures 1B, 2B, and 3B, where the arc sites are clustered in the upper half of the rooms for the circuits that run up and down (blue ellipse) and in the approximate center of the room for the circuits that run left to right (green ellipse). It could then be hypothesized that the origin of each fire would be located within the overlapping section of the ellipses. This can be done in the absence of any other data such as fire patterns, witness statements, and fire dynamics.

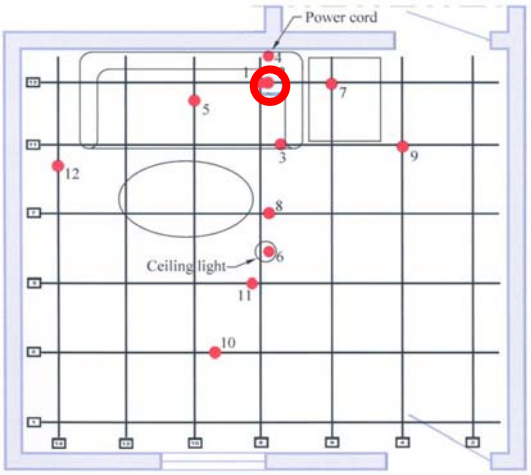

Figure 1A – Arc mapping diagram of Test 1 of the West/Reiter study.

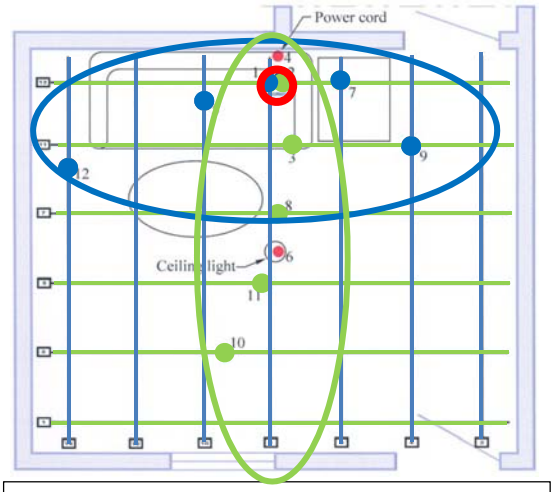

Figure 1B – Diagram with circuits and sites color-coded.

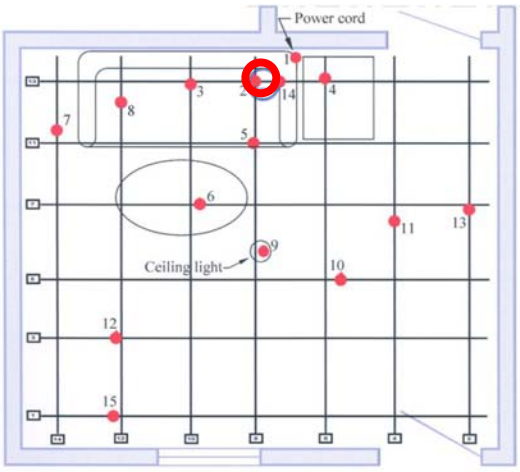

Figure 2A – Arc mapping diagram of Test 2 of the West/Reiter study.

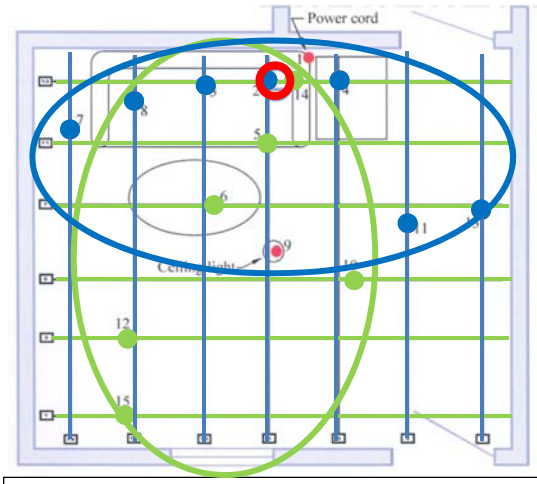

Figure 2B – Diagram with circuits and arc sites color-coded.

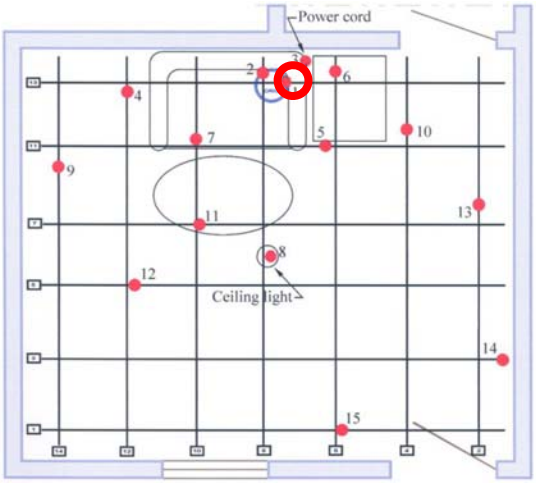

Figure 3A – Arc mapping diagram of Test 3 of the West/Reiter study.

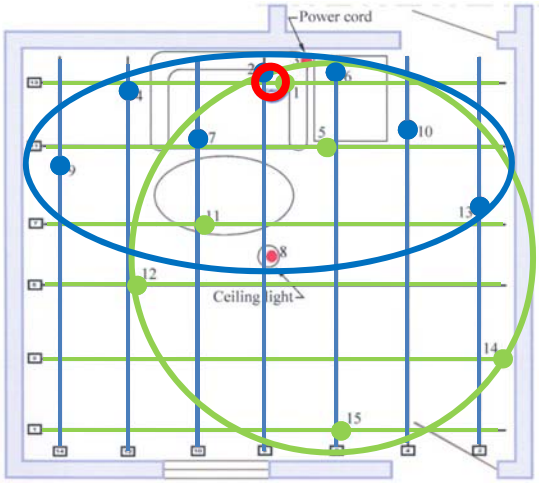

Figure 3B – Diagram with circuits and arc sites color-coded.

Despite the lack of any clear patterns, the investigator could still hypothesize that the area of origin is located within the area where the ellipses overlap, thereby ruling out a large portion of the compartment. Therefore, it is misleading for the author to say that the arc sites "diametrically opposite" the area of origin invalidates arc mapping methodology. This opinion fails to account for the circuit topology within the structure, which is an important consideration in the analysis of any arc mapping procedure. West and Reiter's results show that arcing events occur in the presence of a ceiling jet, and that the timing of these events will follow the progression of the ceiling jet [5]. This information was not accounted for in the author's analysis.

The author presents a statistical analysis concluding that arc mapping is useful in less than 1% of fire investigations. The data used to perform these calculations was drawn from two unrelated studies using different materials and test methodologies, and the author only focuses on the ability of the investigator to determine the direction of fire movement, not the area of origin. The author determined that, based on two studies [4, 6], there is a 5% probability of a second arc occurring, with 29% of all arcing events resulting in sever-arcs. There is also a 50% probability for a downstream arcing location. Based on these numbers, the probability of arc mapping being helpful is calculated by the author as 0.05 x 0.29 x 0.5 = .0073, or .7%.

In both of these studies, the test conditions were not representative of all conditions that may be encountered in the field, such as circuit configuration and routing changes, different types of wire/cable, and building construction. The wiring was also not installed in a manner consistent with real-world conditions; in both studies, the wiring was installed exposed on the ceiling. It is also important to note that West and Reiter used materials found in the U.S. with a 120/240 V, 60 Hz system while Carey used wiring found in the U.K. and a 230 V, 50 Hz system. All tests were conducted within a single compartment. The author has also not accounted for certain variables, such as where in the electrical cycle the arc was initiated, the speed at which the cable/conductor insulation was damaged by fire, and the response of circuit protection devices. The variability of the arcing damage observed in [4] shows that many factors play a role in the damage produced during an arcing event. For the author to imply that these events, calculated from a relatively small data set, form strong correlations only suits the purpose of discrediting arc mapping and oversimplifies the analysis by not considering numerous variables. For these reasons, the author's calculations and resultant conclusions about the utility of arc mapping are misleading.

The author has not considered other factors that can be used in conjunction with arc mapping to establish the origin and/or the direction of fire spread, including electrical activity on multiple circuits and the timing of circuit faults with other documented events such as loss of power as captured by photographs, video, or viewed by witnesses. The use of fire patterns and fire dynamics in conjunction with arc mapping is also missing from this analysis. Furthermore, the author does not address the statistical analysis performed by Carey [6].

In order to properly apply arc mapping in a fire investigation, the investigator must have a strong knowledge of electricity, building construction, fire dynamics, and wiring practices. Furthermore, the fire investigator should consider how fuel loads, ventilation factors, and protective barriers may influence the behavior of the electrical system under fire conditions.

Conclusions

Arc Mapping: New Science or New Myth? argues for the elimination of arc mapping as one of the four ways to determine the area of origin of a fire and the reduction in the utility of the process. This was supported by the author's opinions that three "myths" are used in current methodologies:

1) *An abundance of arc beads at a given locale means that fire originated in that area, while a paucity of arc beads indicates that it did not.*
2) *When multiple arcs are present on a circuit, the direction of arcing will necessarily proceed upstream towards the power source.*
3) *If an appliance is the victim of a fire, internal arcing will be primarily near the exterior of the unit, while arcing deep inside indicates a fire origin at that place.*

As previously stated, none of these "myths" are included in curriculums taught by the ATF, IAAI, or the National Fire Academy, and none are included in industry-accepted texts, such as NFPA 921. These "myths" would be better classified as hypotheses that have since been discarded or amended into what is used in the industry today. As such, to discredit an entire methodology based on these hypotheses is misleading. Further guidance and education to the investigative community is more appropriate.

The proposal that arc mapping is only applicable to less than 1% of fire investigations is based on a flawed analysis of data gathered from two unrelated studies with different methodologies, materials, test conditions, and with limited data sets. The author assigned concrete probabilities to variables in the calculations, which oversimplifies the analysis. The opinion that arc mapping applies to less than 1% of investigations is misleading.

Recommendations

It is the recommendation of the FRL that fire investigators remember that arc mapping involves the knowledge gained from an analysis of the electrical system and that it is only one tool available in their toolbox. Arc mapping should be used in conjunction with witness statements, fire patterns, and fire dynamics to determine the area of origin, the direction of fire spread, and in the development of a timeline. The investigator should have a working knowledge of the principles of electricity and electrical wiring and should consider how fuel loads, ventilation, and protective barriers may influence the behavior of the electrical system under fire conditions. They should also be aware of limitations, such as incorrectly identifying arc melting artifacts, and the destruction of wiring due to structural collapse and post-flashover fire exposure. The FRL also recommends further training and research on the principles and use of arc mapping in fire investigation.

References

[1] Babrauskas, V. (2017). Arc Mapping: New Science or New Myth? *Fire and Materials*. San Francisco, CA

[2] *NFPA 921: Guide for Fire and Explosion Investigation*. (2017). Quincy, MA: National Fire Protection Association.

[3] Kovarsky, R. (2016). Arc Mapping and Appliance Investigations. In *International Symposium on Fire Investigation Science and Technology* (pp. 293-302). Sarasota, FL: National Association of Fire Investigators.

[4] West, L., & Reiter, D. (2005). Full-Scale Arc Mapping Tests. In *Fire and Materials*. San Francisco, CA.

[5] Reiter, D. [Personal communication].

[6] Carey, N. J. (2009). *Developing a Reliable and Systematic Analysis for Arc Fault Mapping* (Doctoral Dissertation). University of Strathclyde.